FISHERIES AGENCY, MINISTRY OF AGRICULTURE AND FORESTRY
TOKAI REGIONAL FISHERIES RESEARCH LABORATORY
ICHITARO GENSHO, *DIRECTOR*

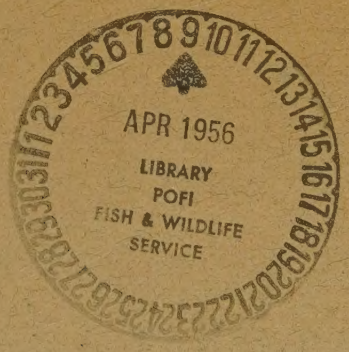
SPECIAL PUBLICATION No. 5

THE RECENT SEA FISHERIES IN JAPAN AND THEIR RESOURCES

RECENT TRENDS IN PLANKTONOLOGICAL RESEARCHES IN JAPAN

THE CHEMICAL COMPOSITION, VOLUME, WEIGHT, AND SIZE OF THE IMPORTANT MARINE PLANKTON

(*Translated from Japanese*)



December, 1955

Tokyo

EDITORIAL NOTE

This series is intended to include those papers which have been submitted to international scientific meetings and are deemed to be adequate for further circulation. Reports in preliminary stages will also be published in this form from time to time for the purpose of throwing the high light upon some of important works requiring immediate dissemination.

FISHERIES AGENCY, MINISTRY OF AGRICULTURE AND FORESTRY
TOKAI REGIONAL FISHERIES RESEARCH LABORATORY
ICHITARO GENSHO, *Director*

Special Publication No. 5

CONTENTS

Page

The Recent Sea Fisheries in Japan and their Resources . . . . . Zinziro Nakai 1

Recent Trends in Planktonological Researches in Japan . . . . . Zinziro Nakai 9

The Chemical Composition, Volume, Weight, and Size of the Important Marine Plankton (*Translated from Japanese*) . . . . . Zinziro Nakai 12

THE RECENT SEA FISHERIES IN JAPAN AND THEIR RESOURCES*

Zinziro NAKAI**

ABSTRACT

ALTHOUGH THE PRESENT PAPER has been intended for Agenda, Technical Items, 14.24; Other Groups, *e.g.*, Clupeoids, Engraulids, etc., excluding tunas, the author has come to show a general picture of recent Japanese sea fisheries exploiting various species along with notable indications of their abundances. Among commercial landings as of 1953 tabulated by biological groups (table 1), the most important is Isospondyli amounting to 970,000 metric tons, with the sardine as the representative species. Next is Scombroidei, about 800,000 tons, represented by the mackerel; the third, Cephalopoda belonging to Mollusca, amounts to 510,000 tons and consists mostly of the common squid. The total production of various types of fisheries in that year was 4,550,000 tons (table 2).

Some notable facts in the catch and fluctuation in the abundance for the period of 1950 through 1954 may be seen in table 3. There are 16 important species, each of which exceeds over 50,000 tons in its annual catch. The common squid is most abundantly caught (about 500,000 tons on the five-year-average), followed by sardine (310,000 tons) and anchovy (253,000 tons). Neritic-pelagic fisheries are the most important type yielding the greater majority of catch including ten species out of the sixteen.

Studies on fluctuations in the resources have revealed that increasing catches of anchovy and horse mackerels are likely ascribed to the augmentation of their abundance, while saury pike are on the increase most probably because of a large scale application of fishing lights as reported in the other paper—IPFC/C55/TECH 28 (CG). Catch of Alaska pollack is also in upward trend. Species which remarkably decreased in the 1954 catch were herring and sardine. In either case, however, no evidence seems to point to depletion in the abundance due to overfishing. A cause of an abrupt decrease in the common squid catch as happened in 1953 and 1954 has not become available.

Fishing seasons, grounds, and important gears are explained according to major species along with year-to-year fluctuations of seasonal catches (table 4).

INTRODUCTION

THE TERM "SEA FISHERIES" is often used here in Japan to denote all aspects of the industry except the efforts to propagate and harvest aquatic animals in the shallow sea and fresh waters. In 1953 the total production of fisheries falling under this category amounted more than 4,550,000 metric tons. It is these fisheries that supply the greater part of animal protein to the population of this country. At the same time, they are regarded as one of the most significant items of Japan's industries that supports the fishing communities which occupy an important niche in the economic life of the nation.

* A paper—IPFC/C55/TECH 13 (Sea)—prepared in the terms of reference to Provisional Agenda 14.24, and submitted to the 6th session of Indo-Pacific Fisheries Council, FAO, Tokyo, September 30 through October 14, 1955.

** Chief Biologist. Marine Resources Section, Tokai Regional Fisheries Research Laboratory, Tokyo, Japan.

A brief account of neritic-pelagic fisheries in the sea adjacent to Japan was submitted to the 5th meeting of IPFC held in Bangkok in 1954 (IPFC/C54/TECH 12). The report, which was prepared on the basis of information for the 1951–53 period furnished by several specialists in different species, included a wide range of topics such as general pictures of the fisheries and fluctuations in the stocks, particularly, symptomatic evidences, if any, of overfishing ; biological characteristics ; latest status of research organizations and programs and problems requiring international co-operation.

The present report has been prepared in an attempt to illustrate more recent features of the sea fisheries, fluctuations in their stocks, and interpretations of some of the results obtained from recent investigations.

AMOUNT OF SEA FISHERIES CATCH BY BIOLOGICAL GROUPS

Based upon consolidated figures of commercial fishery landings as of 1953, the amounts of catch by sea fisheries are indicated in table 1 according to taxonomical groups together with the name of representative species which was most plentifully caught within each group, and the number of important species under the group, *i.e.*, species whose cath amounts to more than 50,000 metric tons a year. In addition to these landings compiled by the Survey and Statistics Division, Ministry of Agriculture and Forestry, there are quantities of catch such as whales and allied mammals ; salmon and king crabs in the northern North Pacific, tunas and white-lip-pearl-oysters in the areas of lower latitudes produced by mother-boat-type expeditions and demersal fish in the South China Sea caught by trawlers. These items of catch are shown in table 2 on the basis of data provided by the Fisheries Agency.

As is obvious in tables 1 and 2, the greater majority, or 94% of the total catch, consists of animals, amounting to 4,300,000 tons. Particularly fish represents 72%. Of the fish, Isosponderyli and Acanthopterygii form 37% and 30%, respectively, dominating over other suborders. Except for whales, the number of species whose catch amounts to more than 50,000 tons is 16. Of them 13 species belong to Teleostei, 11 of which again are included into either Acanthopterygii or Isosponderyli mentioned above.

RECENT CATCH OF IMPORTANT SPECIES AND FLUCTUATION IN THEIR STOCKS

Table 3 shows the annual catch of important species, each amounting to nearly 50,000 tons or more, produced in the recent five years from 1950 to 1954. Out of 16 important species ten belong to the so-called neritic-pelagic fisheries, whereas,

TABLE 1. AMOUNT OF CATCH BY SEA FISHERIES, JANUARY—DECEMBER, 1953*
Unit: 1,000 Metric Tons.

Biological Classification	Amount of Catch	Subtotals	Representative Species	Number of Major Species**
Animals		4,011		
Phylum Vertebrata		3,217		
Class Pisces		3,217		
Order Elasmobranchii		96		
Suborder Asterospondyli	24		Great blue shark[a]	0
Suborder Tectospondyli	36		Dog fish[b]	0
Other sharks	19			0
Suborder Batoidei	17		Whip ray[c]	0
Order Teleostei		3,121		
Suborder Isospondyli	970		Sardine[d]	4
Suborder Iniomi	23		Lizard fishes[e]	0
Suborder Apodes	21		Sharp-toothed eel[f]	0
Suborder Synentognathi	262		Saury pike[g]	1
Suborder Acanthopterygii		1,211		
Tribe Percesoces	7		Mullet[h]	0
Tribe Percomorphi		925		
Group Scombroidei	799		Mackerel[i]	5
Group Percoidei	126		Yellow croaker[j]	0
Tribe Cataphracti	213		Atka mackerel[k]	1
Tribe Jugulares	66		Sand launce[l]	1
Suborder Heterosomata	128		Slime flounder[m]	0
Suborder Anacanthini	253		Alaska pollack[n]	1
Other fishes	252			
Phylum Mollusca		698		
Class Cephalopoda	510		Common squid[o]	1
Class Gastropoda	10		Abalone[p]	0
Class Bivalvia	115		Short-necked clam[q]	1
Other Shellfishes	63			0
Phylum Arthropoda		70		
Class Crustacea	70		Red crab[r]	0
Phylum Echinoderma	12			
Other Marine Animals	14			
Plants		253		
Division Phaenophyceae	197		Kelp[s]	1
Other Seaweeds	55			
(Total Amount)	4,263			

Scientific Name:

a *Prionace glauce* (Linné)
b *Squalus suckleyi* (Girard)
c *Dasystis akajei* (Müller et Henle)
d *Sardinops melanosticta* (Temminck et Schlegel)
e Synodontidae
f *Muraenesox cinereus* (Forskal)
g *Cololabis saira* (Brevoort)
h *Mugil cephalus* Linné
i *Pneumatophorus* spp.
j *Pseudosciaena manchurica* (Jordan et Thompson)
k *Pleurogrammus azonus* Jordan et Metz
l *Ammodytes personetus* Girard
m *Microstomus ache* (Jordan et Starks)
n *Theragra chalcogramma* (Pallas)
o *Ommatostrephes sloani pacificus* Steenstrup
p *Haliotis gigantia* Gmelin
q *Venerupis philipinarum* (Adams et Reeve)
r *Chionoecetes opilio* O. Fabricius
s *Laminaria* spp.

* Excludes yields of whaling, other factory ship fisheries, pearling in the Arafura Sea and trawling in the South China Sea, which are shown in table 2.

** Indicates the number of species belonging to the same biological classification, the species whose catch amounts to more than 50,000 metric tons.

TABLE 2. TOTAL AMOUNT OF CATCH BY SEA FISHERIES, 1953
Unit: 1,000 Metric Tons

Grand Total	Sea Fisheries in Table 1	Whaling in Antarctic and Other Areas	Salmon and Crab Fishings in North Pacific	Tuna Fishing by Factory Ship	Trawling in South China Sea	Pearling in Arafura Sea
4,553	4,263	250	17	8	14	1

TABLE 3. ANNUAL CATCH OF IMPORTANT SPECIES[a], 1950–54[b]
Unit: 1,000 Metric Tons

Species	1950	1951[b]	1952	1953	1954	Average	Kind of Fishery
Herring[c]	160	168	268	275	132	200	Neritic-Pelagic Fisheries
Sardine	258	396	302	344	246	309	〃 〃
Round herring[d]	72	65	45	53	48	57	〃 〃
Anchovy[e]	147	282	290	243	304	253	〃 〃
Saury pike	126	129	226	254	293	206	〃 〃
Skipjack[f]	85	101	86	73	96	88	Oceanic Fisheries
Albacore[g]	54[h]	31	60	52	52	50	〃 〃
Mackerel	188	151	269	235	297	228	Neritic-Pelagic Fisheries
Horse mackerel[i]	72	93	204	239	250	152	〃 〃
Yellowtail[j]	32	44	59	49	46	46	〃 〃
Atka mackerel	42	166	139	158	114	124	Demersal Fisheries
Sand launce	—	—	—	66	43	—	Neritic-Pelagic Fisheries
Alaska pollack	153[k]	188	209	225	241	203	Demersal Fisheries
Common squid	469[l]	607	601	420	399	499	Neritic-Pelagic Fisheries
Short-necked clam	70	—	—	79	64	—	Estuarine Fisheries
Kelp	100[m]	101	158	142	157	132	Seaweeding
Others	936	985	1,551	1,355	1,428	1,335	
Grand Total	2,964	3,507	4,467	4,263	4,210	3,882	

a Excludes yields of whaling, other factory ship fisheries, pearling in the Arafura Sea and trawling in the South China Sea.
b Compiled on the basis of the calendar year except 1951 which covers 12 months ending on March 31, 1952.
c *Clupea pallasii* Cuvier et Valenciennes
d *Etrumeus micropus* (Temminck et Schlegel)
e *Engraulis japonica* (Houttuyn)
f *Katsuwonus pelamis* (Linné)
g *Germo germo* (Lacepede)
h Includes other tunas
i Caranginae, chiefly the common horse mackerel, *Trachurus japonicus* (Temminck et Schlegel)
j *Seriola quinqueradiata* T. et S.
k Includes cod
l Includes other squids
m Includes other seaweeds

Atka mackerel and Alaska pollack are only two species falling under demersal fisheries which were caught abundantly enough to be reckoned in the present tabulation. The scarcity of important species among the trawling catches is attributable to a fact that these catches consist of numerous varieties, but seldom of a single species, of demersal fish. In the sequence of decreasing significance the species whose catch exceeds over 200,000 tons on the five-year-average are the common squid, sardine, anchovy, mackerels, saury pike, and herring.

Table 3 points to some species whose catch during the period under review fluctuated more than the others. In particular, the amount of landings has been on the increase one year after another in case of the fishes such as horse mackerel, saury pike and Alaska pollack. The greater catch of the first is presumed to be due to an increase in the population, whereas, improved efficiency of the operation using fishing lights is thought to have contributed to a great augmentation of the saury catch as discussed in another paper submitted by the author to the present session of the Council—IPFC/C55/TECH 28 (CG).

The catch of herring and sardine remarkably decreased in the 1954 season. A further decrease that occurred in the catch of the spring herring in 1955 gave rise to a fear as to whether the phenomenon was indication of a depletion in the herring stock. In any event, no convincible evidence has been made available for a view that the decrease could have resulted from overfishing. On the other hand, it has been forecast that the sardine catch in the 1955 season will hardly be less than that of 1954. The results of investigations carried out so far in regard to the Japanese sardine do not seem to verify that the decreasing catch is the consequence of depletion in the abundance of the stock. Instead, there are good reasons to believe that the large-sized sardine on their way to the southern migration must have been halted as they were disturbed by abnormally high temperatures in the waters northwest of Kyushu and the southern part of the Japan Sea from the autumn to the winter of both 1953–54 and 1954–55 periods, thereby resulting in reduced catches in the succeeding season.

The fishery for anchovy has revealed a remarkable increase in its catch in the successive years of the postwar period ; particularly the catch in the 1954 season was the greatest that had ever been landed. The information made available by the surveys suggests that the anchovy stock has probably obtained a maximum of abundance in recent years.

The flying squid, *Ommatostrephes sloani pacificus*, forms the greater majority of the common cuttlefish, landings of which well surpassed the level of 600,000 tons in 1951 and 1952. Although the catch indicated a sharp decline to 400,000 tons in the succeeding two years, it has not been certain if that resulted from sudden impairment in the stock.

FISHING SEASONS, GROUNDS AND GEARS

On the bases of information furnished by the Survey and Statistics Division and various reports by Regional Fisheries Research Laboratories, a summary of fishing seasons, busiest months, fishing areas, major grounds, and principal gears operated in 1953 is prepared in table 4.

TABLE 4. FISHING SEASONS*, GROUNDS, AND PRINCIPAL GEARS FOR IMPORTANT SPECIES

Species	Fishing Season*	Busiest Month*	Fishing Area	Major Fishing Ground	Principal Gear
Herring.....	Spring	Apr.	Around Hokkaido	Japan Sea off Hokkaido	Fixed nets
Sardine.....	Throughout the year	Sept.-Oct.	All coastal areas	Northwest of Kyushu	Round hauls
Round Herring	〃 〃	Apr., Nov.	Nearly all coastal areas	Northwest of Kyushu, south of Japan Sea	〃 〃
Anchovy	〃 〃	Aug.-Sept., Nov.	All coastal areas	Central coast on Pacific	〃 〃
Saury pike	Fall	Oct.	Pacific area	Northeastern coast on Pacific	Stick-held-lift net
Skipjack	Early summer to early fall	May, Jul.	〃 〃	〃 〃	Pole and line
Albacore	Early half of the year	Jun.	〃 〃	High sea of Pacific	Long line
Mackerel	Throughout the year	May, Dec.	All coastal areas	Northwest of Kyushu	Round hauls
Horse mackerel.....	〃 〃	Jul., Nov.	Nearly all coastal areas	Northwest of Kyushu, central coast on Pacific	〃 〃
Yellowtail	〃 〃	Mar., Nov.	All coastal areas	Central coast on Pacific	Fixed nets
Atka mackerel	〃 〃	Apr.-May, Nov.	Northern areas	Around Hokkaido	Trawl nets
Sand launce	Spring to summer	Apr.-Jun.	Nearly all coastal areas	Seto Inland Sea	Boat seine
Alaska pollack	Throughout the year	Dec., Apr., Jul.	Northern areas	Around Hokkaido	Trawl nets
Common squid	Later half of the year	Oct.-Nov.	All coastal areas	Tsugaru Straits	Pole and line
Short-necked clam ..	Throughout the year	Jul.-Aug.	South of central coasts	Tokyo Bay, Ise Bay, Ariake Sea	Dredge
Kelp	Later half of the year	Aug.	Around Hokkaido	Off Kushiro, Nemuro	Sickle
Sea Fisheries	Throughout the year	Apr., Nov.			

* Prepared on the basis of the 1953 season.

In the monthly total of the catches during the period under study there are two outstanding peaks in April and October. A substantial portion, or over 40%, of the April catch is represented by the herring landed on Hokkaido. The peak in October is constituted of abundant catch of squid in the Tsugaru Straits, suary in the Tohoku region and the medium-sized sardine in the northwestern waters of Kyushu. Generally speaking, the catch is much greater in the later half than in the early half of the year. The occurrence of fishing season in 1953 shown in table 4 is nearly in agreement with that of the average year, although the busiest month for some species such as anchovy, mackerel, horse mackerel, and yellowtail, appeared a month or two earlier or later than usual. Attention should be drawn to the fact that the sardine fishery from September to October 1953 was in its height while in the coordinate months in 1954 the fish were not caught in such abundance. An immediate cause of this phenomenon may be ascribed to fluctuation of the medium-sized sardine (0-age fish) in the autumn when they were in the waters northwest of Kyushu—particularly in Goto-Nada, the sea between the Goto Islands and the mainland of Kyushu. Tracing back to the chains of causes, it has been conjectured that an unusually high temperature of water in the winter made the parent fish linger half-way in their southerly migration as described before. However, as to the peak in May made up mainly of the large-sized sardine netted in the Japan Sea no remarkable change from the average year has been noted.

For most organisms existing in the cold current such as herring, saury, pollack and kelp, on the one hand, the principal fishing season occurs once a year. On the other hand, there are many cases in which the busiest season comes twice a year. It is so for the species such as sardine, round herring, anchovy, mackerel, horse mackerel, and yellowtail, which would migrate back and forth along the coastal waters with an area south of the cold front as the northern limit.

Regarding fishing areas, herring, Atka mackerel, pollack, saury and kelp are almost exclusively produced in the coastal waters around Hokkaido and off the northern part of Honshu. On the contrary, fishing areas for a number of migratory fishes living in the warm current are extensively distributed north to south along both side of the Japanese Islands. The fishing seasons vary according to the locality of the fishing grounds.

The fishes which are caught only in the sea on the Pacific side but hardly in the Japan Sea are skipjack and albacore. The greater majority of saury are netted in the northern waters on the Pacific coast, as well. The Seto Inland Sea produces most of the sand launce. The short-necked clam are from the shallow sea enclosed in bays locating from the central part to the south along the Pacific coast.

A great many varieties and modifications of fishing gears are in use according

to sizes and ecological conditions of animals to be caught, oceanographical and geographical circumstances of fishing grounds, economic factors and practices of the fishing communities. As indicated in table 4, round hauls are the principal gears for sardine, round herring, anchovy, mackerel, and horse mackerel. The herring and yellowtail are entrapped in fixed nets. Trawl nets are for Atka mackerel and pollack, boat seines for sand launce, pole-and-line for skipjack as well as squid, and the long line is used for albacore.

Although the above principal types of gears employed in the 1953 season are supposedly similar to those in previous years in regard to fishes for which they are operated, some marine organisms are often caught by other types of gears not specifically classified in the table. Adopted for enhancing the efficiency of operation, auxiliary equipments such as sonar-fish-finders and fishing lights, have made considerable development in recent years. Since they are being successfully and prevalently employed in capturing certain species, a progressive increase in the use of auxiliary gears is anticipated.

RECENT TRENDS IN PLANKTONOLOGICAL RESEARCHES IN JAPAN[1]

Zinziro NAKAI[2]

ABSTRACT

IN REGARD TO INSTRUMENTS and methods for collecting plankton and quantitative determination thereof, conspicuous trends are discussed on the basis of these employed in Japan for the 1954 programmes.

When a number of research institutions work together under a common objective, there has been a noticeable tendency to use standardized methods designed in accordance with their objective and economic conditions in carrying out a programme. Brief descriptions of the methods have been made to some systematic programmes conducted on a relatively large scale, together with their aims, covering areas, and kinds of plankton to be collected.

Referring to independent studies, important aspects pertaining to planktonological researches, such as kinds of institutions, purposes, methods, and subject-matter, are mentioned.

In 1954 planktonological researches in Japan made substantial advance and presented a favorable opportunity for adequate standardization of the methods.

IN MARINE PLANKTON INVESTIGATIONS recently conducted in Japan, there has been a noticeable tendency for research institutions to work together under a common objective, using standardized methods for the collection and quantitative determination designed in accordance with the economic and other conditions of the participating organizations. Such cooperative systems are often found in research programmes operating for the purpose of directly contributing to commercial fisheries.

A Cooperative Programme throughout Japan: The spawning surveys, one of the components of *Iwashi*[3] Resource Investigation Programme, have been carried out on a country-wide scale since 1949 in cooperation with Regional Fisheries Research Laboratories and Prefectural Experimental Stations assigned with the work. Although considerable numbers of research boats, *e.g.*, more than 30 as of the 1954 programme, were employed for estimating the stock of the fishes and studying ecological conditions such as spawning grounds and seasons, it was possible to follow uniform and precise methods in the studies.

The collection of material was conducted by vertical hauls to the surface from a depth reached by the length of wire of 150 meters, using a conical net with the opening of 45 cm across, mesh size similar to Müller gauze No. 3. In an exception when a 60 cm net was used, the value was recalculated to make it comparable to that of the 45 cm net. Eggs and larvae of the fish from every haul were enumerated

1. A paper—IPFC/C55/TECH 15 (Misc.) submitted to the 6th session of Indo-Pacific Fisheries Council, FAO, Tokyo, September 30 through October 14, 1955.
2. Chief Biologist, Marine Resources Section, Tokai Regional Fisheries Research Laboratory, Tokyo, Japan.
3. Commercial name of fish including sardine, anchovy and round herring.

by the individual; plankton samples in general were subjected to the wet weight determination, and when necessary, some of them were sorted into species for individual counting.

Projects in the Pacific Area: Other important plankton surveys in the Pacific coast and the high sea of the North Pacific were undertaken by about 20 research boats in regard to investigations of salmon fishing grounds, whaling exploration, oceanographical and meteorological observations related to fishing prospects and rice harvests in the Northeastern Region. With a few exceptions, similar methods as described above were applied to studies of microplankton in these surveys as well. In the collection of microplankton by vertical hauls from a 50 meter layer to the surface a Kitahara's net, 24 cm opening, mesh of Müller gauze No. 13, the oldest, yet most prevalent type in this country was used. In addition to the 45 cm net, a larger type of conical net, 1.3 m opening, has been horizontally towed for collecting pelagic eggs and larval fish.

Research in Other Areas: Some 20 research vessels have been engaged in plankton surveys in connection with the Tsushima Warm Current Exploration in the coastal waters on the East China Sea and the Japan Sea, where the 45 cm net was also in use for macroplankton. The participants in the programme are regional laboratories, local fisheries and educational institutions in the areas. A modification introduced for the 1954 programme was the limitation of the vertical hauls to 50 meters instead of 150 meters. The horizontal towing of 1.5 m net or 1.3 m net mentioned above was also performed to collect eggs and larval fish in the Tsushima current investigation.

Miscellaneous Planktonological Studies: Apart from these systematic programmes under way on large scales, other aspects of planktonological studies are independently pursued by fisheries institutions, meteorological organizations and certain educational institutions. Some of their subject matter are: taxonomy, biogeography: planktonological studies of water masses in relation to propagation of the useful marine organisms or to predators and red waters; other ecological interests such as life history and feeding habits of marine organisms, productivity of the sea; deep scattering layers; water pollution related to plankters; effect of water discharged from a power-dam to be built close to the sea, etc.

It is likely that these works mentioned above do not always adopt the same methods for collection and quantitative determination of materials, probably because very few attempts, if any, have been made to set up an agreement upon the methods in accordance with the purposes and practical conditions of the surveys. However, one thing which is nearly common in these studies is the use of the Kitahara type net for collecting microplankton. For distribution surveys of nannoplankton, water

sampling is employed by meteorological observatories and related agencies. In the quantitative determination of plankters individual counting of specimens or its modifications such as methods of settling volume, displacement volume, and wet weight, are most frequently used. In technological fields, examination and improvement of the methods and devices for collection as well as quantitative determination have been attempted.

Thus, it may be said that researches into various fields of planktonology have made substantial advance in this country during recent years, presenting a more favorable opportunity than ever for cooperation in the work with standardization of methods.

THE CHEMICAL COMPOSITION, VOLUME, WEIGHT, AND SIZE OF THE IMPORTANT MARINE PLANKTON

(*Translated from Japanese**)

Zinziro NAKAI**

ABSTRACT

OF TEN SPECIES of the important marine plankton studied in the present work, seven belong to copepods and the other three to euphausiids, diatoms and amphiods respectively. The chemical composition of nine species analysed in this work have never been reported. The samples were collected with various types of nets in the sea adjacent to Japan as shown in table 1, then they were preserved in formalin.

Crude fat (ether extracts) was determined with a Soxhlet's apparatus; nitrogen, by a modification of Kjeldahl's method; and crude ash, by combustion. Silicate was treated in the ash with HNO_3 and HCl. The results thus obtained are shown in tables 2 and 3 a, b, c, d.

In *Calanus plumchrus*, the percentage of the dry weight to the wet one varied as greatly as from 12 to 23%, possibly due to differences in the fat content. The fat content of *Calanus plumchrus* (53.3–53.9%) was considerably higher, while the ash content of copepods (0.96–3.3%) lower, than those reported by previous authors. The silicate content of *Coscinodiscus janischii* (51.6%) was a little higher than those recorded by Brandt and by Brandt and Raben for the mixed plankton.

I. INTRODUCTION

CHEMICAL COMPOSITION of marine plankton, since it was studied by Brandt (1898) with the collections from Kiel Bay for the purpose of estimating the productivity of organisms in a unit amount of sea water, has drawn attentions of several workers mentioned below. However, the studies made by Brandt (1898), Brandt and Raben (1919–1922), Moberg (1926), Wimpenny (1929), Günther (1934), and Cooper (1935), are chemical analyses of mixed species of plankton as a whole. Chemically quantitative determinations of particular species carried out by Klem (1932), Orr (1934 a, b), Marshall, Nicholls and Orr (1934), and Cooper (1939), do not deal with more than eight specific organisms including copepods and sagittas, two species for each; euphausiids, cirripeds, medusa, and a larval fish, one species for each. Klem was concerned only in the fat content, while Cooper (1939) did not assess it. Of the above workers, only Brandt, Brandt and Raben analysed silica for mixed species of their collections. However, no information has been made available for the amounts of protein and silica contained in species of marine diatoms.

The purpose of the present study is to obtain data for research on the pro-

* Translated from the Japanese text published in the Journal of the Oceanographical Society of Japan, Vol. 1, Nos. 1–2, 1942, in cooperation with Mr. Masao Ishida, Tokai Regional Fisheries Research Laboratory. Footnotes on pages 12–15 and for figure 3 have been added on this occasion.

** Present position: Chief Biologist, Marine Resources Section, Tokai Regional Fisheries Research Laboratory, Tokyo, Japan.

ductivity of sea water as well as food for the Japanese sardine (*Sardinia** *melanosticta* Temminck and Schlegel) and other marine animals. In this paper are dealt with seven species of copepods, and one species for euphausiids, amphipods and diatoms.

II. SPECIES OF THE PLANKTON STUDIED

*Calanus plumchrus*** Marukawa (Japanese: Akahige-karamijinko): An important plankton most abundantly found in the stomach of sardines occurring off the east coast of Korea. In June 1940 and in the same month of the following year oceanographical surveys were carried out in the Sea of Japan in connection with the sardine investigations. On the basis of the surveys the total standing crops of zooplankton in the month of June was estimated to approximate 15,000,000 metric tons in wet weight in the layers above a depth of 150 meters in the western half of the Japan Sea separated by a line drawn between Niigata of Japan and Cape Povorotni, Maritime Provinces, U.S.S.R. Of that amount about 10,000,000 tons were supposed to be *C. plumchrus* mainly in the fifth copepodite. T. Yamada (1938) reports that the adult male, a little immature, was found from the stomach of Alaska pollack (*Theragra chalcoglamma* Pallas). His collection was a single record of the adults made available so far, as no occurrence of the female had ever been reported. However, during survey cruises of the R.V. *Misago-Maru* conducted by the author in 1940 and 1941, a large numbers of the adults, both male and female, could be obtained from depths ranging from 200 to 2,000 meters nearly all over the Sea of Japan and in the areas off Muroran and Kinkazan on the Pacific coasts.

It was suggested by S. Motoda and Dr. S. Kokubo (1933) that *C. plumchrus* might belong to the same species of *C. cristatus* Kröyer, only being in a different stage of development. However, the author has confirmed the specific differences between these two copepods by comparing their developments from copepodite stage I up to the adult (stage VI). They can be distinguished from each other by apparent difference in size, and by the presence of the head crest in *C. cristatus*, while devoid in the other. They also vary in several aspects such as the first antenna, first and second maxillae, first swimming feet, fifth legs of the adult male, mouth, and digestive canals. A report will be prepared later in this regard.

Calanus cristatus Kröyer (Japanese name newly assigned: Oh-karamijinko): One

* It is considered reasonable to refer the genus name *Sardinia* to *Sardinops*.

** Some workers describe *Calanus plumchrus* Marukawa as synonym of *C. tonsus* Brady. However, the author has confirmed from examination of Brady's type specimen that they are certainly different species. Because, in the type specimen there are several distinct spines on the distal inner margin of the second basipodites of the II–IV swimming feet, whereas Marukawa's *plumchrus* is completely devoid of them. In addition, a number of other differences in morphological characters exist between these species. In this regard a detailed report is under preparation.

of essential types of food for the Japanese sardine and other fishes. It was O. Tanaka (1938) who for the first time found the adult in the Sagami Bay. The author collected this species in waters off Muroran of Hokkaido, Seishin (Chungjin) and Busuitan (Cape Boltin) of Korea during the cruises of the R.V. *Misago-Maru* in and after May 1940. Particularly, a remarkable knowledge on the life history of the plankton was supplied when the pelagic eggs and nauplii were found together with the adult in vertical hauls of a closing net from depths of 1,000 to 2,000 meters off Seishin and Busuitan.

Calanus helgolandicus (Claus)? (Japanese name newly assigned: Hidariashinaga-karamijinko): A controversy as to whether this is different from *C. finmarchicus* (Gunner)—Japanese: Kita-karamijinko—does not seem to have been settled yet, though we will not touch it here. The species is one of the most important plankton next to *C. plumchrus* as food for the sardine and other fishes occurring in the coastal waters of Korea. Our studied the annual fluctuation in chemical composition of *C. finmarchicus* occurring at a station occupied off Plymouth, England.

*Pseudocalanus elongatus** Boeck (Japanese: Ashinaga-karamijinkomodoki);

Paracalanus parvus Claus (Japanese: Hime-parakaramijinko);

Euchaeta japonica Marukawa (Japanese newly assigned: Nihon-yukemijinko): These three also inhabit in the Korean waters and are important forms of food for sardines and other fishes.

Acartia clausi Giesbrecht (Japanese: Togebuto-akarumijinko): One of copepods most abundantly occurs along the western and northern coasts of Kyushu during months from February to May when the sardine spawn there.

Euphausia pacifica Hansen (Japanese newly assigned: Tsunonashiami): When Hansen (1911) described this plankton as a new species belonging to Euphausiacea, he referred to its distribution in the Japanese waters. Not a single information, however, has been provided since then in respect of the distribution or occurrence in coastal regions of Japan as the species does not seem to have been identified as such by most of workers. But in fact the plankton is produced in a great abundance practically in all the waters adjacent to Japan including the Sea of Japan and the Yellow Sea in which it serves a favorable food for the sardine and mackerels, particularly for the latter occurring off Korea. In addition it forms an important food for whales, as well. The rostrum of this species looks blunt in the upper view as is meant by the Japanese name assigned tentatively to it.

Parathemisto sp. (Japanese newly assigned; Usumurasaki-uminomi): This form of amphipods, valuable food for sardines and mackerels, often emerges to the surface

* Recently the species name *minutes* has come to be considered more acceptable than *elongatus* which has been in prevalent use for years.

layer in a large herd at night. According to T. Yamada (1933) the plankton is supposed to belong to either *Parathemisto abyssorum* or *P. japonica*. As he has pointed out, however, the second antenna is longer than the first. Not only that, but the present species also differs from *P. abyssorum* in regard to the length of segments of the peduncle of the second antenna, and from *P. japonica* in regard to the length of swimming feet. Since any species corresponding to the present one does not seem to be available, a report is under preparation to announce it as a new species, while the Japanese name has been given for tentative use*.

Coscinodiscus janischii A. Schmidt: Of various pelagic diatoms, only this has been collected in the greatest quantity with fairly simple composition.

III. METHODS FOR COLLECTION AND TREATMENT

A majority of the samples was collected off Korea by the R.V. *Misago-Maru* of the Fisheries Experiment Station, Government-General of Chosen, on the occasions of investigating specific quantitative distribution of plankton in the area; the rest being provided by the *Hayabusa-Maru*, fishing experimental boat of the same, and by the *Hokuyo-Maru* and *Kongozan-Maru* of the Experimental Stations of Kankyonan-do and Kogen-do, respectively.

Out of some three thousand samples those which were more abundant in amount and simpler in their composition were used for the study; and particularly the least mixed samples were chosen for the study of smaller plankton, though it was very difficult to find one acceptable for this requirement. Every sample was preserved in formalin** in a separate bottle right after hauling. Presented in table 1 are hauling methods, oceanographical conditions and other information pertaining to the collection.

As shown in the table three different nets used for the surveys are distinguished by type such as 130 cm-ring, 60 cm-ring, and beam trawl. The first two were conical in shape and made of bolting silk of 700 *iri* (a unit of mesh size) as illustrated in figure 1. One had the opening of 130 centimeters in diameter and was horizontally towed from the side on the surface at about two knots for ten minutes. The other, 60 centimeters across the mouth, was used for vertical hauling. The beam trawl, which was primarily designed for collecting larval fish living on the bottom, consisted of double nets, one inside of another. The inner net had a square opening, 1.2 by 0.4 meter and was made of a spliced net or scrim with mesh size as illustrated in

* The present species does not consist with the original description and the figures given by Bovallius to *Parathemisto japonica*. For this reason the author is of opinion that this is different from *P. japonica* Bovallius. However, Dr. T. E. Bowman, the Smithsonian Institution, states in his personal letters to the author to the effect that Bovallius' description and figures were not always accurate and complete and that he still believes the present species to be *P. japonica* Bovallius.

** About 10% concentration.

Table 1.

Sample No.	Organism	Vessel	Position	Date	Time h m	Net*	Method and depth of haul	Oceanographic condition: Layer m	Water temp. °C	Salinity ‰	pH	O_2 cc/L
1	*Calanus plumchrus*	Hayabusa-maru	N 39°48′ E 128 17	4/23/36	6 00	130 *cm* ring	Horizontal surface	0	4.7	33.75		
2	〃	Hokuyô-maru	N 39 56 E 128 21	3/10/37	3 50	〃	〃	0	2.6	33.87		
3	〃	〃	N 38 50 E 129 05	〃	22 35	〃	〃	0	4.5	33.82		
4	〃	〃	N 40 15 E 130 45	5/24/39	18 29	60 *cm* ring	Vertical 150 *m*–0 *m*	0 100	10.5 1.2			
5	*Calanus helgolandicus*?	Misago-maru	N 32 32 E 129 40	1/16/39	16 45	130 *cm* ring	Horizontal surface	0	16.19		8.36	
6	〃	〃	N 35 37 E 135 17	5/31/37	11 20	〃	〃	0	17.88	34.02	8.36	5.62
7	*Calanus cristatus*	〃	N 42 16 E 130 26	3/ 6/35	15 15	Beam-trawl	Horizontal 34 *m*	29	−0.08	34.00	8.08	7.00
8	*Paracalanus parvus*	Hayabusa-maru	N 34 49 E 129 12	5/16/39	17 48	130 *cm* ring	Horizontal surface	0	16.4			
9	*Pseudocalanus elongatus*	Misago-maru	N 41 48 E 130 02	3/ 8/35	6 02	〃	〃	0	1.41	34.04	8.08	6.25
10	*Euchaeta japonica*	〃	N 39 39 E 131 28	7/ 4/35	23 55	Beam-trawl	Horizontal 29 *m*	25	13.65	34.00	8.24	6.51
11	〃	〃	〃	〃	〃	〃	〃					
12	〃	〃	〃	〃	〃	〃	〃					
13	〃	〃	〃	〃	〃	〃	〃					
14	*Acartia clausi*	〃	N 33 51 E 130 15	4/ 2/37	10 25	130 *cm* ring	Horizontal surface	0	13.99	34.56	8.32	5.94
15	*Euphausia pacifica*	Hayabusa-maru	N 35 43 E 129 44	2/27/38	17 35	〃	〃	0	12.7			
16	*Parathemisto* sp. (*Japanese name: Usumurasakiuminomi*)	〃	N 40 46 E 129 54	4/25/36	15 —	〃	〃	0	3.3	33.73		
17	〃	Misago-maru	N 42 22 E 131 03	3/ 7/35	12 25	Beam-trawl	Horizontal 90 *m*	85	−0.98	34.22	8.10	6.84
18	〃	Kongozan-maru	N 37 53 E 130 15	6/ 6/36	16 45	130 *cm* ring	Horizontal surface	0	14.3	33.78		
19	*Coscinodiscus janischii*	Misago-maru	N 34 46 E 130 31	4/ 6/39	14 42	〃	〃	0	13.84	34.85	8.36	5.79
			N 34 39 E 130 40	〃	16 10	〃	〃	0	13.83	34.85	8.36	5.86
			N 34 33 E 130 49	〃	17 40	〃	〃	0	13.54	34.67	8.38	6.02

* Meshes of { 130 *cm* (Diameter) ring net: "A" type (fig. 1); 60 *cm* (〃) 〃 : 〃 〃; beam-trawl : "B" type (fig. 2)

Table 2.

Sample No.	Organism	Volume* of org. weighed off *cc*	Number of org. weighed off	Weight		Dry wt./ wet wt. %	Wet weight per *cc* *mg*	Number of org. per *cc*	Wet wt. of one org. *mg*	Mean** length *mm*	Sex ratio and stage %
				Wet *g*	Dry *g*						
1	*Calanus plumchrus*	31.8	1804	9.236	2.131	23.1	291	56.7	5.12	5.03	V 100
2	"	15	1036	3.635	0.784	21.6	242	69.1	3.51	4.50	V 92, IV 8
3	"	10	1026	2.303	0.298	12.9	230	102.6	2.24	4.21	V 100
4	"	68	5670	7.805	0.907	11.6	115	83.4	1.38	3.44	V 40, IV 48 III 10, II 2
5	*Calanus helgolandicus*?	45	15840	15.48	2.414	15.6	344	352	0.98	3.06	♀ 96, ♂ 4
6	"	17	7000	4.2	0.700	16.7	247	412	0.60	2.46	
7	*Calanus cristatus*	64	503	14.08	2.70	19.2	220	7.9	28.0	9.4	V 97, IV 3
8	*Paracalanus parvus*	36	417400	13.54	2.158	15.9	377	11590	0.0325	0.80	♀ 88, ♂ 12
9	*Pseudocalanus elongatus*	43	442000	19.44	2.391	12.3	452	10290	0.0439	1.16	♀ 54, ♂ 12
10	*Euchaeta japonica*	27	718	5.13	1.175	22.9	190	26.6	7.14	6.23	♀ 16, juv. 8 ♂ 76
11	"	5.0	84	1.07	0.212	19.8	214	16.8	12.7	7.72	♀ 100
12	"	3.4	100	0.655	0.157	24.1	193	29.4	6.55	6.06	♀ 100
13	"	—	46	0.163	0.024	14.7	—	—	3.5	4.81	juv. 100
14	*Acartia clausi*	38	430000	13.16	1.393	12.1	227	7420	0.0306	1.03	♀ 88, ♂ 12
15	*Euphausia pacifica*	11.5	1334	28.45	4.31	15.1	247	11.6	21.3	15.7	♀ 58, ♂ 42
16	*Parathemisto* sp. (*Usumurasakiaminomi*)	35	1938	18.5	2.826	15.3	529	55.4	9.54	7.19	♀ 100
17	"	2	38	0.488	0.098	20.1	244	19	12.8	9.1	
18	"	3	76	0.840	0.115	13.7	280	25.3	11.1	8.5	
19	*Coscinodiscus kanshiki*	132	3420000	6.8	0.40	5.9	61	30000	0.0198	0.393	

* Settled volume. ** Length. { Copepoda, from tip of head to end of furca. Euphausia, from tip of rostrum to end of telson. Parathemisto, from tip of head to end of telson. Coscinodiscus, diameter.

figure 2. This trawl net was horizontally towed on an intermediate layer or the bottom at about two knots for ten minutes. As all the nets had comparatively large mesh, the samples of diatoms consisted only of *Coscinodiscus janischii* and larger forms, while smaller forms had likely been filtered off.

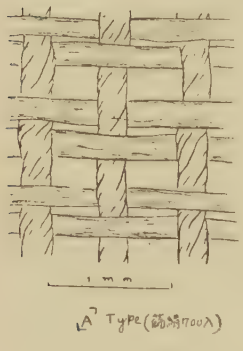


Figure 1.

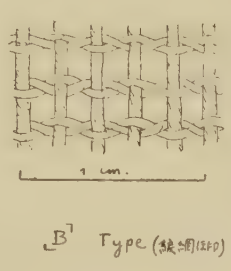


Figure 2.

In selection, a forceps was used to pick out large plankton such as *Calanus plumchrus*, *C. cristatus*, *C. helgolandicus*?, *Euchaeta japonica*, *Euphausia pacifica*, *Parathemisto* sp. (Usumurasaki-uminomi). For small plankton, samples as pure as possible were chosen as stated above, then specific uniformity was strickly secured by removing different species however small they might be in number and size. At the final stage of selection both small plankton and the large were examined under a microscope.

Ordinary thermometers calibrated either up to one tenth or one half a degree Centigrade were used for measuring the water temperature on the surface, and a Richter-Wiese type for deep layers. The Knudsen method was applied to the salinity determination, the McClendon method to pH, and the Winkler method improved by us to oxygen. The amount of each sample used was measured by three methods: settled volume, wet weight and dry weight. For the settled volume, a plankton suspension was permitted to stand in a bottle with formalin for 24 hours. To measure the wet weight the sample was placed on a filter paper in a funnel and washed several times by pouring distilled water; the plankton was rolled on another blotting paper until no moisture was visible on the paper with the naked eye; and the material was balanced. Then the sample was subjected to drying thermostatically at 95°C. so as to determine the constant dry weight.

The length of two large plankton, *Euphausia pacifica* and *Parathemisto* sp. (Usumurasaki-uminomi), was measured, while being kept straight, by means of dividers with the naked eye. For other organisms the length was determined using an ocular micrometer or on the basis of the figures drawn with a help of a camera lucida under a microscope. The length was defined differently according to organisms as given in the footnote of table 2.

Crude fat (ether extract) was determined by a Soxhlet apparatus. To determine the amount of crude protein, the value of nitrogen obtained with the Kjeldahl method was multiplied by a factor, 6.25. The distillation of nitrogen was carried out through steaming and subsequent cooling. The materials were ignited in a clay crucible, and

reduced into the constant amount of ash which was again treated by nitric acid and hydrochloric acid in the ordinary method to obtain silicic acid (SiO_2).

IV. RESULTS AND DISCUSSION

Table 2 shows the settled volumes, number of individuals, wet and dry weights, coefficients between these factors, sex ratio, stage, and average body length of the sample plankton. Indicated in tables 3-a, -b, -c, and -d, are the weight and the number of organisms, the amounts determined for chemical components, the percentages to the wet and dry weights, and the average amounts contained per individual.

The ratio of dry weight to the wet weight of zooplankton ranged between 12 to 24 per cent with 17 per cent on the average. However, for *C. plumchrus*, the ratio varied in such remarkable a range as 12 to 23 per cent, most likely depending on the fat amount of individuals; for the greater the amount of fat, the higher was the ratio.

Difference in the wet weight per unite of the settled volume seems to depend mostly on mixing rates of various stages as the case with *C. plumchrus*. Samples containing a greater number of younger stages yielded a smaller amount in wet weight.

Crude Fat: As is seen in table 3-a, crude fat contained in *C. plumchrus* was found greater than 31 per cent on the dry weight base, and sometimes as much as 53.3 and 53.9 per cent, exceeding over 47 per cent obtained by Orr (1934 b) from the copepodid stage V of *C. finmarchicus*, collected on July 3, 1932, the amount which was the highest fat gain that had ever been recorded from marine plankton. It is interesting to remind that with such plentiful fat in the body, *C. plumchrus* exists in waters off Korea in association with oil-enriched sardines whose important food is this very species.

The fat content per individual of *C. plumchrus* shows such remarkable a variance as 1 : 6 even among the same copepodid V stage. As the changes seem to depend on biological and environmental conditions such as seasons and depths of waters in which the plankton occurs, further studies will be made in these regards. The gain of fat from dried samples of *C. helgolandicus*? (mainly ♀) was only 5-11 per cent this time, and considerably smaller than 11-30 per cent obtained from the female of *C. finmarchicus* by Orr (1934 b). Data made available on different occasions are also indicative of seasonal and geographical changes in the fat content of the present species, which are left to be discussed on other opportunities. With some expectable fluctuations in the value, fat gain of *Euchaeta japonica*, showing 33.7 per cent, was small in comparison with 33-44 per cent obtained by Orr (1934 a) from *Euchaeta norvegica*.

Table 3-*a*.

Sample No.	Organism	Dry weight of organism analysed for fat estimation *g*	Number of organism analysed for fat estimation	Amount of fat *g*	Fat % on wet weight	Fat % on dry weight	Fat content of one organism *mg*
1	*Calanus plumchrus*	1.744	1477	0.9290	12.3	53.3	0.629
2	〃	0.700	921	0.3770	11.6	53.9	0.409
3	〃	0.298	1028	0.1136	4.9	38.1	0.115
4	〃	0.307	1918	0.0964	3.6	31.4	0.0503
5	*Calanus hèlgolandicus?*	1.552	10210	0.1710	1.7	11.0	0.0167
6	〃	0.616	6160	0.0318	0.87	5.2	0.0052
7	*Calanus cristatus*	1.996	371	0.721	6.93	36.1	1.94
8	*Paracalanus parvus*	1.428	275500	0.272	3.0	19.1	0.000987
9	*Pseudocalanus elongatus*	1.540	284500	0.266	2.1	17.3	0.000934
10	*Euchaeta japonica*	1.175	718	0.396	7.5	33.7	0.553
14	*Acartia clausi*	1.543	389800	0.089	0.70	5.8	0.000228
15	*Euphausia pacifica*	3.000	929	0.082	0.41	2.7	0.0883
16	*Parathemisto* sp. (*Usumurasakiuminomi*)	0.990	678	0.392	6.1	39.6	0.578

Table 3-*b*.

Sample No.	Organism	Dry weight of organism analysed for protein estim. *g*	Number of organism analysed for protein estim.	Amount of Protein *g*	Protein % on wet weight	Protein % on dry weight	Protein content of one organism *mg*
1	*Calanus plumchrus*	0.300	254	0.104	8.0	34.8	0.409
4	〃	0.527	3294	0.282	6.2	53.4	0.086
5	*Calanus helgolandicus?*	0.530	5486	0.399	11.7	75.2	0.073
7	*Calanus cristatus*	0.520	97	0.278	10.3	53.4	2.86
8	*Paracalanus parvus*	0.500	96500	0.351	11.1	70.1	0.00363
9	*Pseudocalanus elongatus*	0.500	92500	0.358	8.8	71.5	0.00387
10	*Euchaeta japonica*	0.261	159	0.135	11.8	51.8	0.849
14	*Acartia clausi*	0.503	136000	0.416	10.0	82.6	0.00306
15	*Euphausia pacifica*	0.500	155	0.397	12.0	79.3	2.55
16	*Parathemisto* sp. (*Usumurasakiuminomi*)	0.500	342	0.243	7.4	48.7	0.710
19	*Coscinodiscus janischii*	0.357	2880000	0.115	1.9	32.2	0.000040

Table 3-*c*.

Sample No.	Organism	Dry weight of organism analysed for ash estimation *g*	Number of organism analysed for ash estimation	Amount of ash *g*	Ash % on wet weight	Ash % on dry weight	Ash content of one organism *mg*
1	*Calanus plumchrus*	1.0330	875	0.0248	0.55	2.4	0.0283
4	〃	0.2906	1817	0.0028	0.11	1.0	0.00154
5	*Calanus helgolandicus*?	1.4782	9720	0.0418	0.44	2.8	0.0043
7	*Calanus cristatus*	1.9674	366	0.0336	0.33	1.7	0.0917
8	*Paracalanus parvus*	1.3762	265700	0.0402	0.46	2.9	0.000151
9	*Pseudocalanus elongatus*	1.3800	255000	0.0320	0.28	2.3	0.000125
10	*Euchaeta japonica*	1.0742	655	0.0222	0.48	2.1	0.0339
14	*Acartia clausi*	0.8725	236000	0.0292	0.40	3.3	0.000124
15	*Euphausia pacifica*	2.3640	731	0.1690	1.07	7.1	0.231
16	*Parathemisto* sp. (*Usumurasakiuminomi*)	1.4792	1013	0.1370	1.42	9.3	0.135
19	*Coscinodiscus janischii*	0.0258	22050	0.0140	3.20	54.2	0.00063

Table 3-*d*.

Sample No.	Organism	Dry weight of organism analysed for SiO_2 estim. *g*	Number of organism analysed for SiO_2 estim.	Amount of SiO_2 *g*	SiO_2 % on wet weight	SiO_2 % on dry weight	SiO_2 content of one organism *mg*
1	*Calanus plumchrus*	1.0330	875	0.0027	0.06	0.26	0.0023
4	〃	0.2906	1817	0.0000	0.00	0.00	0.00000
5	*Calanus helgolandicus*?	1.4782	9720	0.0000	0.00	0.00	0.000000
7	*Calanus cristatus*	1.9674	366	0.0055	0.05	0.28	0.015
8	*Paracalanus parvus*	1.3762	265700	0.0043	0.05	0.31	0.000012
9	*Pseudocalanus elongatus*	1.3800	255000	0.0006	0.01	0.04	0.000002
10	*Euchaeta japonica*	1.0742	655	0.0000	0.00	0.00	0.00000
14	*Acartia clausi*	0.8725	236000	0.0047	0.07	0.54	0.000023
15	*Euphausia pacifica*	2.3640	731	0.0025	0.02	0.11	0.0015
16	*Parathemisto* sp. (*Usumurasakiuminomi*)	1.4792	1013	0.0000	0.00	0.00	0.00000
19	*Coscinodiscus janischii*	0.0258	22050	0.0133	3.04	51.6	0.00060

Fat of *Parathemisto* sp. was found worth noticing as it was as high as almost 40 per cent when no report on chemical analysis of amphipods had been available so far. Whereas, unexpectedly low was the fat gain of *Euphausia pacifica*, falling short of 3 per cent. No fat was determined for *Coscinodiscus*.

Crude Protein: As is evident from figure 3, the percentage of crude protein of zooplankton (crustacean) was quite in an opposite relationship with that of fat. The sum of fat and protein was approximately constant, representing 82–89.5 per cent, and on the average 86.1 per cent. The fact may be interpreted that protein and fat form a greater portion of chemical composition in these species, change in the rest hardly affecting percentage of the above sum.

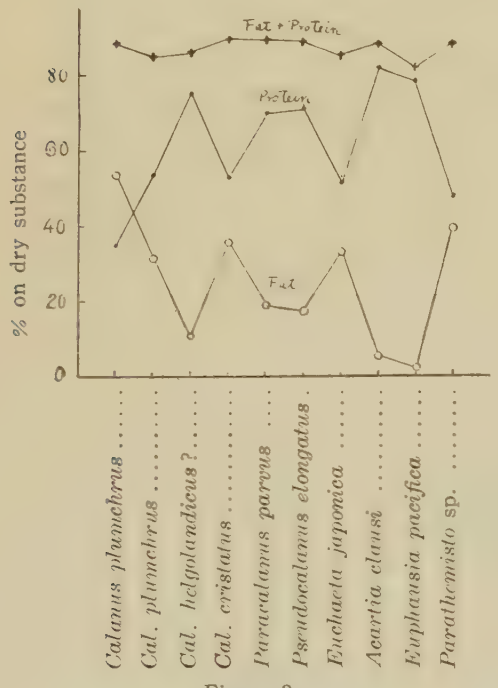


Figure 3.
Remarks: The lines connecting the plotted values have been drawn merely to indicate the relative positions of the values between different samples.

Protein of the diatom was 32.2 per cent on the dry weight base, standing within the range of 13.45–38.5 per cent as gained by Brandt (1898) and Brandt and Raben (1919–22) from samples largely containing diatoms.

Crude Ash: Of copepods *Acartia clausi* had 3.3 per cent of ash on the dry weight base, six others remaining less than 3 per cent. According to Orr (1934 a, b), the only planktologist that has ever reported on this item by species, the amounts of ash of *Euchaeta norvegica* and *C. finmarchicus* were 4 and 3.6 per cent respectively. Therefore the present value of ash is supposed to be a minimum so far reduced from plankton. Brandt (1898) and Brandt and Raben (1919–22) gained ash of 10.92–15.40 per cent upon examining copepods in a substantial part of samples. The values, however, are not comparable with the present ones as theirs were from impure samples mixed with diatoms. Ash of *Coscinodiscus janischii* was 54.2 per cent lying between 48.40–68.85 per cent obtained by Brandt and Raben (1919–22) from the samples consisted of diatoms for the most part.

Silicic Acid: As has been stated before, a quantitative determination of silicic acid contained in pure samples of zooplankton was carried out for the first time on this occasion. However, very small amounts of silicic acid, about 0.5 per cent at best, were found with the present samples. Four species including *C. plumchrus*

had it as little as 0.00%. Another sample of *C. plumchrus* showed silica 0.26 per cent. Such a discrepancy in the amount of silica in the same species may strongly suggest possibility that these species are feeding on diatoms and that the amount of diatoms left in the degistive organs would affect the silica content. Brandt and Raben (1919–22) reported of 0.05–0.18 per cent as the gains from samples mostly consisted of copepods.

Yielded from *Coscinodiscus janischii* was silicic acid 51.6 per cent which was a little over 47.16–51.26 per cent gained by Brandt (1898) from the samples predominated by diatoms, but by far exceeded the value, 9.17–27.10 per cent, found by Brandt and Raben (1919–22).

V. SUMMARY

1. Chemical analyses of ten important species of marine plankton including seven species of copepoda, a species for each of euphausiids, amphipods, diatoms, have been carried out, determining their volumes, weights, the numbers of individuals, and the relationships thereof. Except for *Calanus helgolandicus*?, the present study seems to be the first attempt that has ever been made at examining chemical constituents of these plankton.

2. The analytical results are tabulated below.

Sample No.	Organism	% of composition based on dry weight				Content in one organism *mg*			
		Fat	Protein	Ash	SiO_2	Fat	Protein	Ash	SiO_2
1	*Calanus plumchrus*	53.3	34.8	2.4	0.26	0.629	0.409	0.0283	0.0023
2	〃	53.9	—	—	—	0.409	—	—	—
3	〃	38.1	—	—	—	0.115	—	—	—
4	〃	31.4	53.4	0.96	0.00	0.0503	0.086	0.00154	0.00000
5	*Calanus helgolandicus*?	11.0	75.2	2.8	0.00	0.0167	0.073	0.0043	0.000000
6	〃	5.2	—	—	—	0.0052	—	—	—
7	*Calanus cristatus*	36.1	53.4	1.7	0.28	1.94	2.86	0.0917	0.015
8	*Paracalanus parvus*	19.1	70.1	2.9	0.31	0.000987	0.00363	0.000151	0.000012
9	*Pseudocalanus elongatus*	17.3	71.5	2.3	0.04	0.000934	0.00387	0.000125	0.000002
10	*Euchaeta japonica*	33.7	51.8	2.1	0.00	0.553	0.849	0.0339	0.00000
14	*Acartia clausi*	5.8	82.6	3.3	0.54	0.000228	0.00306	0.000124	0.000023
15	*Euphausia pacifica*	2.7	79.3	7.1	0.11	0.0883	2.55	0.231	0.0015
16	*Parathemisto* sp.	39.6	48.7	9.3	0.00	0.578	0.710	0.135	0.00000
19	*Coscinodiscus janischii*	—	32.2	54.2	51.6	—	0.000040	0.00063	0.00060

3. Fat content of *Calanus plumchrus* was 53.3 and 53.9 per cent on the basis of dry weight, and found much greater than what had been gained from marine plankton by other workers.

4. Ash content of copepods was 0.96–3.3 per cent this time and lower than that reported so far.

5. Silica content of *Coscinodiscus janischii* was 51.6 per cent, the gain which was slightly greater than those obtained by Brandt, Brandt and Raben from mixed samples substantially consisted of diatoms.

In conclusion the author wishes to acknowledge Mr. Keizo Nishida, Director, the Fisheries Experiment Station, Government-General of Chosen, for his kindness in reading the original manuscript. Laborious assistances given to him by numbers of his colleagues in collecting materials are deeply appreciated as well.

REFERENCES

Brandt, K. 1898. Beiträge zur kenntniss der chemischen zusammensetzung des planktons. Wiss. Meeresunters., Vol. 3, Abt. Kiel, pp. 43–90.

Brandt, K. and Raben, E. 1919–1922. Zur kenntniss der chemischen zusammensetzung des planktons und einiger bodenorganismen. Wiss. Meeresunters., N. F., Vol. 19. Abt. Kiel, pp. 175–210.

Cooper, L. H. N. 1935. The determination of phosphorus and nitrogen in plankton. Journ. Mar. Biol. Assoc., Vol. XIX, pp. 755–760.

— 1939. Phosphorus, nitrogen, iron and manganese in marine zooplankton. Ibid., Vol. XXIII, pp. 387–390.

Günther, E. R. 1934. Observations on the fatty constituents of marine plankton—I. Biology of the plankton. Jour. Exp. Biol., Vol. XI, pp. 173–197.

Hansen, H. J. 1911. The genera and species of the order Euphausiacea, with account of remarkable variation. Bull. de l'Institut Oceanographique No. 210, pp. 26–29.

Klem, A. 1932. Contributions to the study of the oils of marine crustacea—I. The oils of *Meganyctiphanes norvegica* M. Sars and *Calanus finmarchicus* (Gunn.). Hvalradets Skrifter, Nr. 6, pp. 1–24.

Marshall S. M., Nicholls A. G. and Orr A. P. 1934. On the biology of *Calanus finmarchicus*—V. Seasonal distribution, size, weight and chemical composition in Loch Striven in 1933, and their relation to the phytoplankton. Jour. Mar. Biol. Assoc. Vol. XIX, pp. 793–827.

Moberg, E. G. 1926. Chemical composition of marine plankton. Third Pan-Pacific Science Congress, Tokyo, pp. 233–236.

Orr, A. P. 1933–1934a. Weight and chemical composition of *Euchaeta norvegica* Boeck. Roy. Soc. Edinburgh, Vol. LIV, pp. 51–55.

— 1934b. On the biology of *Calanus finmarchicus*—Part IV. Seasonal change in the weight and chemical composition in Loch Fyne. Journ. Mar. Biol. Assoc., Vol. XIX, pp. 613–632.

Tanaka, O. 1938. Note on *Calanus cristatus* Kröyer. Japan. Journ. of Zool., Vol. VII. pp. 599–601.

Wimpenny, R. S. 1934. Preliminary observations on the fat content of the plankton on the English herring grounds in the North Sea. Minist. of Agr. and Fish. Invest., Ser. II, Vol. II, No. 5, pp. 1–23.

Motoda, S. and Kokubo, S. 1933. *Calanus cristatus* Kröyer on seitai oyobi keitai ni tsuite, (On morphology and ecology of *Calanus cristatus* Kröyer). Plankton Jiho (Bull. of Planktology), No. 6, p. 60.

Yamada, T. 1933. Fuyuseibutsu no bunpu ni kansuru chosahokoku, (Investigation report on distribution of plankton). Chosen-Sotokufu Suisanshikenjo Kaiyochosayoho (Report on the oceanographic investigation, Fisheries Experiment Station, Government-General of Chosen), No. 7, Appen. pp. 1–10.

— 1938. Gyokyakurui sushu no bunpu ni kansuru chiken hoi, (Supplements to taxonomical knowledge on some species of copepods). Suisan-gakkaiho (Bull. Soc. Fish. Sci.), Vol. VII. pp. 183–188.

List of Special Publications

*No. 1: On Fishery for "Iwashi" (Sardine, Anchovy and Round Herring) and Research of its Resources in the Japanese Waters, by Zinziro Nakai.
Issued October, 1952.

*No. 2: On Quantitative Distribution of Plankton Reproduced in the Northern Pacific, by Zinziro Nakai.
Issued October, 1952.

No. 3: A Report on Oceanographical Investigations in the Salmon Fishing Grounds of the North Pacific, 1952 and 1953, by Nobuo Watanabe.
A Preliminary Report on Surveys of Plankton and Salmon Stomach Contents from the North Pacific, 1952, by Zinziro Nakai and Koji Honjo.
Issued January, 1954.

No. 4: Species of Food Plankton for Baleen Whales in the Sea Adjacent to Japan, by Zinziro Nakai.
Preservation of Frozen Whale Meat Produced in the Antarctic Ocean, by Keishi Amano.
Recent Development in the Freshness Test, by Keishi Amano.
Issued July, 1954.

No. 5: The Recent Sea Fisheries in Japan and their Resources, by Zinziro Nakai.
Recent Trends in Planktonological Researches in Japan, by Zinziro Nakai.
The Chemical Composition, Volume, Weight, and Size of the Important Marine Plankton (*Translated from Japanese*), by Zinziro Nakai.
Issued December, 1955.

The above publications are available free from the respective author, the Tokai Regional Fisheries Research Laboratory, Tsukishima, Chuo-ku, Tokyo, Japan.

* Out of print.

Printed by
Kokusai Bunken Insatsusha
Chiyoda-ku, Tokyo.